PHYSIOLOGY OF THE SENSORY SYSTEM

Sensory Receptors

AFCM

Learning objectives:

By the end of this lecture you must be able to:

1. **Define sensory receptors.**
2. **Classify receptors according to the type of the stimulus.**
3. **Name the properties of sensory receptors, and explain specificity.**
4. **Describe receptor potential .**
5. **Describe the relation between the sensation & the frequency of discharge in a sensory nerve & the intensity of stimulation.**
6. **Explain receptor adaptation.**
7. **Explain coding for sensory information.**

Sensory receptors are specialized structures that act as both:

- **Detectors: They detect changes in the external or internal environment of the body.**
- **Transducers: They convert the energy of the change they have detected into electrical impulses.**

They are located at the peripheral ends of sensory neurons (specialized cell), mainly in receptors that are concerned with vision, hearing, equilibrium & taste.

Or, they may be a part of the neuron itself (examples cutaneous receptors & Pacinian corpusles (touch receptor).

They are excitable structures, since they respond to stimuli by generating an action potentials.

According to *the type of stimulus*, receptors can be classified into:

1) Mechanoreceptors :

Respond to mechanical stimuli and include:

- **Touch, pressure and vibration receptors located in the skin.**
- **Proprioceptors located in muscles, tendons and joints.**
- **Baroreceptors located in the aortic arch and carotid sinus.**
- **Stretch receptors located in the alveoli of the lungs and right atrium.**

2) Thermoreceptors :

Stimulated by thermal form of energy and detect changes in temperature and include:

- **Cold receptors.**
- **Warmth receptors.**

3) Chemoreceptors :

Stimulated by chemical forms of energy as taste, odder, and oxygen content in the blood; including:

- **Taste receptors.**
- **Olfactory receptors.**
- **Glucoreceptors and osmoreceptors in the hypothalamus.**

4) Nociceptors :

Stimulated by any form of energy potent enough to cause tissue damage.

5) Electromagnetic receptors :

Respond to the electromagnetic waves of light. Include the rods and cones in the retina of the eye.

Properties of receptors :

a. *Differential sensitivity (specificity):*

- **Each receptor is most sensitive to one particular type of stimulus called its *adequate stimulus*.**
- **The sensory fibre from the receptor terminates in an area of the brain that gives the sensation perceived by the receptor.**
- **The sensation perceived as a result of stimulation of a receptor is called *modality of sensation*.**
- **Some receptors can be stimulated by stimuli other than their adequate stimulus provided the intensity of stimulation is sufficiently high, but will still giving its own specific modality of sensation.**
- **For example, the adequate stimulus for retinal receptors is light. However, receptors do respond to other forms of energy than the adequate one but the threshold for those nonspecific stimuli is much higher (mechanical stimulation of the eye as in trauma is seen as light).**

- **Differential sensitivity of receptors is illustrated by**

Muller's law of specific nerve energies **which states that " each receptor is most sensitive to one specific type of stimulus called its adequate stimulus giving rise to one type of sensation** ***regardless of the method of stimulation*** **because the sensation perceived depends on the area in the brain ultimately activated.**

b. Excitability :

This is the ability of the receptor to respond to stimuli.

- **At rest, the receptor is in the polarized state (with a resting membrane potential about -70 mV).**
- **However, if it is stimulated by** ***inadequate stimulus,*** **it is partially depolarized due to increased Na^+ influx secondary to Na^+ channel activation.**
- **This state of partial depolarization of the sensory nerve ending is called the** ***receptor or generator potential*****, and its magnitude is proportionate to the intensity of the stimulus (it increases with the increase in the threshold of the stimulus).**
- **The receptor potential is passively conducted to the first node of Ranvier (by local circuits of current flow) causing its depolarization, and if this reaches the firing level (summation of the receptor potentials), it initiates an action potential that is propagated via the afferent nerve to the CNS.**

Properties of the receptor potential are:

1. **It is a local, unpropagated potential whereas action potentials are propagated.**
2. **It is a graded potential i.e. it does not obey the all or none rule.**
3. **It has no refractory period, so it can be summated.**
4. **It is not blocked by local anaesthetics, whereas action potentials are blocked by these drugs.**

c. Adaptation:

Definition:

This is a decline in the frequency of discharge of action potentials from receptors that occurs on maintained stimulation by constant strength stimuli. Its degree varies with the type of receptor.

1. **Rapidly adapting receptors (phasic receptors):**

   In which the impulses declines rapidly in spite of maintained stimulation. Example: *touch receptors (particularly Meissner's and Pacinian corpuscles*), the rapid adaptation of which is important to avoid unnecessary and excessive sensations that might be irritating (e.g. there is no need to continuous information of the CNS about the presence of clothes).

2. **Slowly adapting receptors:**

   These are called the tonic receptors because they continue discharging as long as they are stimulated. They include mainly *the pain receptors* & *muscle spindles* in which the slow adaptation is important because the continuous discharge of the pain receptors elicits protective reflexes that prevent tissue damage by noxious agents, while that of the

muscle spindles allows the CNS to detect continuously the body posture & position of the limbs.

Mechanisms of adaptation

It may be due to one or more of the following mechanisms:

1. **Gradual closure of the Na+ channels (which decreases the magnitude of the receptor potential and, consequently the frequency of discharge).**
2. **Gradual decrease of the excitability of the first node of Ranvier.**
3. **Loss of the stimulus energy in the surrounding tissues by constant stimulation.**
4. **Accommodation of the afferent nerve fibre to the generator potential (receptor potential).**

Coding of sensory information :

It is the ability of the nervous system to discriminate (or identify) the modality, locality and intensity of the various sensations, although all types of sensations are transmitted from their receptors to the higher centers via specific sensory pathways in the same form (i.e. as action potentials).

a. Modality discrimination (Specificity) :

- **Discrimination of the modality of a sensation by the brain depends on the adequate stimulus to which the receptor is specialized and on the area of the brain ultimately activated.**

b. Locality discrimination (projection):

- **It depends on the fact that each receptor has a specific pathway to the sensory cortex where different parts of the body are represented.**
- **Stimulation of a sensory pathway anywhere along its course to the sensory cortex produces sensation referred to the location of the receptor.**
- **This effect is called *"law of projection",* and it is clear in patients whose limbs are amputated for any reason, who may feel severe pain in the phantom limb (non-existing limb) due to irritation of the sensory nerves at the site of amputation.**

c. Intensity discrimination

The discrimination of the sensation intensity depends on the following factors:

a. **The number of activated receptors: This increases as the stimulus intensity is increased (recruitment of receptors).**
b. **The discharge frequency from the activated receptors: A high discharge frequency is interpreted by the higher centres as an increased intensity of the sensation.**
c. **The state of nerve centres: In cases of CNS depression e.g. as a result of severe oxygen lack or hypoglycaemia, the sensations become dull and their intensity is decreased.**

Good luck